NO_x Emission Reduction by Oscillating Combustion

Fuel-rich and fuel-lean zones reduce NO_x emissions and increase furnace efficiency

High-temperature, natural gas-fired furnaces – especially those fired with preheated air – produce large quantities of NO_x emissions. Although switching from preheated air to industrial oxygen can increase efficiency and reduce NO_x, oxygen is significantly more costly than air and may not be compatible with the material being heated.

This project focuses on a new technology that reduces NO_x emissions while increasing furnace efficiency for both air- and oxygen-fired furnaces. Oscillating combustion is a retrofit technology that involves the forced oscillation of the fuel flow rate to a furnace. These oscillations create successive, fuel-rich and fuel-lean zones within the furnace. The load heats up faster due to the more luminous fuel-rich zones, a longer overall flame length, and the breakup of the thermal boundary layer. As a result, heat-up times shorten, thereby increasing furnace productivity. It also reduces the heat going up the stack, thus increasing efficiency. The fuel-rich and fuel-lean zones also produce substantially less NO_x than firing at a constant excess air level. The longer flames and higher heat transfer rate reduce overall peak flame temperature thereby, reducing additional NO_x formation from eventual zone mixing and combustible burnout from the rich zones.

Researchers found that oscillating combustion can increase furnace efficiency substantially while reducing NO_x emissions on many types of industrial furnaces using conventional burners. Efficiency gains of up to 5% and NO_x reductions of 28% to 55% were recorded. With minor modifications to the gas supply systems on furnaces, and no modifications to the burners or furnaces themselves, installation of the oscillating combustion system involved minimal downtime and transparency to normal furnace operation. It required only the addition of an oscillating valve on the gas line to each burner, a valve controller for each zone, and adjustment of the gas supply pressure to the valves.

Figure: Oscillating combustion technology.

Benefits for Our Industries and Our Nation

- Improves in heat transfer by up to 13%
- Increases in efficiency or productivity by 5% or more
- Reduces NO_x emissions by up to 75%
- Simple retrofit that does not require modification of burner or furnace

Applications

Oscillating combustion can be applied to many types of furnaces used in steel including box annealing, steel reheating, and ladle drying/preheating. Oscillating combustion can also be used in other high-temperature process industries such as glass, petrochemical, aluminum, cement, and metal heating. This patented technology works with ambient air-, preheated air-, oxygen enriched-air-, or oxy-fuel-fired burners.

Project Participants:

Institute of Gas Technology

Air Liquide

Bethlehem Steel Corporation, Burns Harbor Division

CeramPhysics, Inc.

Columbia Gas Distribution Companies

Gas Research Institute

GT Development Corporation

Nucor Steel, Plymouth Utah

Precision Q Systems

Questar Gas Company

Southern California Gas Company

PROJECT PLANS AND PROGRESS:

Work on this project has included:

- Laboratory application of oscillating combustion to industrial burners Oct. 1996 – March 1999
- Small-scale air-natural gas field evaluation April 1997 – July 1998
- Full-furnace oxy-natural gas oscillating combustion field evaluation Oct. 1997 – Dec. 1999
- Large-scale air natural gas field evaluation July 1997 – March 2001
- Field Demonstration on a 10-MMBtu/h stack annealing furnace March 1998 – Sept. 1998
- Demonstration of oscillating combustion on a reheat furnace Oct. 1999 – Dec. 2003
- Oscillating combustion control system development Oct. 1998 – March 2001

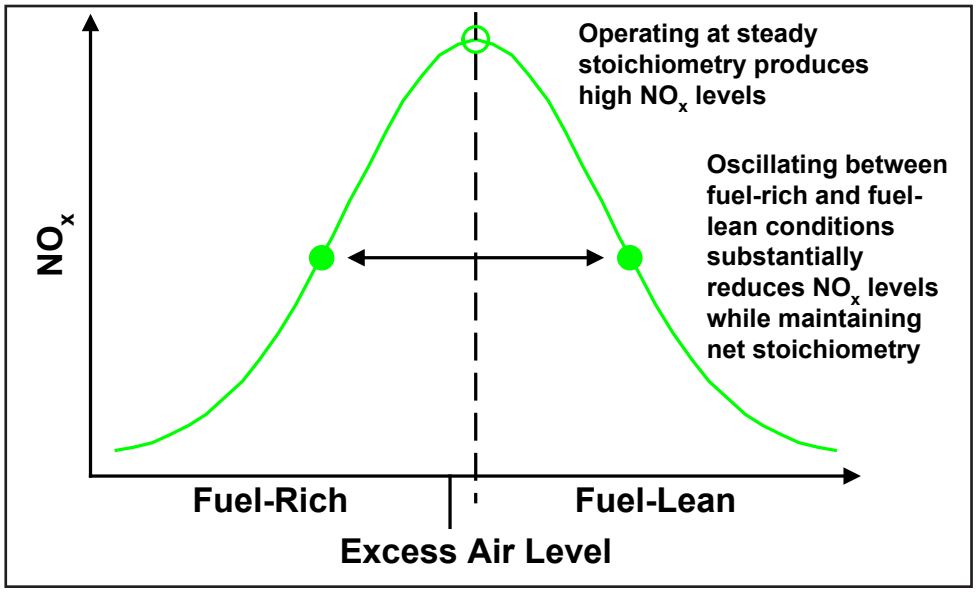

Figure: NO_x levels are lower during operation at oscillating conditions rather than operation at a steady stoichiometry.

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Steel Program

The Steel Industry of the Future (IOF) subprogram is based in the Industrial Technologies Program (ITP) within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. The subprogram works with the steel industry to promote development of more energy-efficient and environmentally sound technology for steel processing. Guided by industry-identified research and development priorities, ITP's steel portfolio addresses those priorities that offer the greatest potential for energy savings in cokeless ironmaking, next-generaton steelmaking, and yield improvement. To learn more about Steel IOF activities, visit the program web site at: www.eere.energy.gov/industry/steel/

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Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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